Faculty of Electrical Engineering

WARSAW UNIVERSITY OF TECHNOLOGY

www.ee.pw.edu.pl

100 years

ISEP

Fun with electric motors and control systems

Warsaw, xx.xx.2027



Bartlomiej Ufnalski, Ph.D., D.Sc.

www.github.com/ufnalski

Warsaw University of Technology

Faculty of Electrical Engineering

Institute of Control and Industrial Electronics

www.isep.pw.edu.pl

Become an engineer!

The optimist sees a glass half full.

The pessimist sees a glass half empty.

One engineer sees **a glass with a safety factor of two**.

Another engineer sees **a glass with a design flaw (it's twice the size it needs to be).**

It depends. Context matters. Engineers don't stop at 'it depends'. The pros back it up!

https://quoteinvestigator.com/2022/04/06/half-full/
https://quoteinvestigator.com/2022/04/08/wrong-size/

Electrify everything!

„If we truly want to get to net-zero emissions, (…) We have to focus on (…) **electrifying all of our end uses** and powering them with emissions-free electricity from **nuclear*** or **renewables**."

Saul Griffith, the founder of Instructables.com



Source: Flaticon.com

*fission now and fusion in the future – Fingers crossed, ITER!

https://www.washingtonpost.com/politics/2022/03/17/why-we-need-electrify-everything-according-saul-griffith/
https://www.iter.org/ (International Thermonuclear Experimental Reactor)
https://www.audible.co.uk/pd/Electrify-Audiobook/B09KSVWP7W

Learn to electrify everything





https://www.ee.pw.edu.pl/studia/kierunki-studiow/elektromobilnosc/
https://adek.pw.edu.pl/
https://www.youtube.com/watch?v=b2hmAKEQB4w

Learn to electrify everything

Fascynujący świat elektromobilności



22/01/2024 Przeczytasz w 4 min



psnm POLSKIE STOWARZYSZENIE NOWEJ MOBILNOŚCI

elektromobilni.pl

https://elektromobilni.pl/44190-2/
https://www.youtube.com/watch?v=f2N3fyN-1e0

How to become an engineer?

Just watching videos or attending lectures, including this one, will not make you an engineer! You have to experiment!

Start with replicating known solutions and then invent your own ones! University laboratories are the perfect place to do that but not the only one. **The good news is that the economic barrier to entry is relatively low. You can play with electronics, control engineering and embedded programming at home as your hobby.**

Instead of buying e.g. a fancy game console, please consider starting your own home laboratory. I ensure you that this will bring more fun than just playing video games, not to mention the possible long-term benefits such as the satisfaction of making stuff. And financial well-being will follow in most cases.

How to become an engineer?

You might ask me: The easy way or the hard way, Bartek? Easy way or the hard way?(*)

My answer is simple: There is no easy way! And it's not just 10 000 hours!(**)

The bad news is that you will spend 80% of your engineering time on correcting your own mistakes. Software developers call it debugging.

The good news is that this process, if well-organized and fed by the scientific method, is very rewarding on many levels.

(*) https://www.imdb.com/title/tt0187078/characters/nm0005148
https://arxiv.org/pdf/1704.03397.pdf
(**) Veritasium an element of truth https://www.youtube.com/watch?v=5eW6Eagr9XA

Let’s set up an electronics lab!

White karate belt:

- logic analyzer (40 PLN, e.g. https://allegro.pl/listing?string=saleae [realistically 8 MS/s])
- multimeter (50 PLN, e.g. https://powermat-hurt.pl/przyrzady-miernicze/1242-uniwersalny-multimetr-cyfrowy-pm-mmt-60-5904067440425.html)
- soldering station (130 PLN, e.g. https://allegro.pl/oferta/stacja-lutownicza-yihua-937d-50w-200-480-esd-safe-11077651651)
- power supply (330 PLN, e.g. https://allegro.pl/oferta/zasilacz-laboratoryjny-30v-yihua-3005d-iv-mocny-12131611237 [0-30V])

Total (after tax): ca. 550 PLN / 120 EUR.

I’m a big believer in walking the talk (practising what I preach) – all of the above are or were in my home arsenal and I’m or was happy with them, even if some of them got replaced over time to e.g. analyze SPIs and DCMIs faster than 2 MHz.



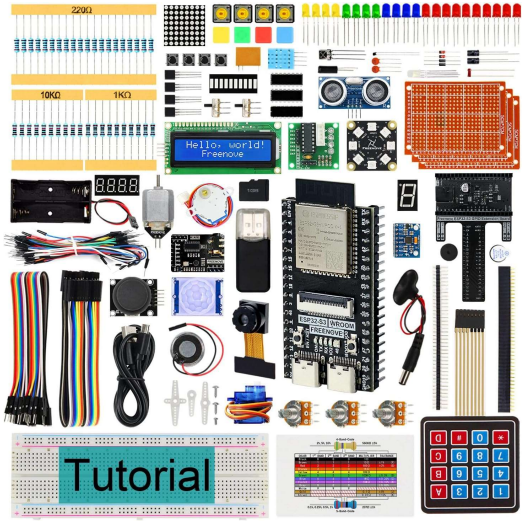
Let’s set up an electronics lab!

White karate belt (cont.):

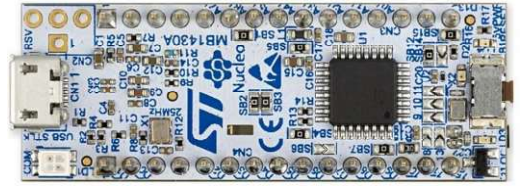
- ESP32-S3 „ultimate” starter kit (300 PLN, e.g. https://www.amazon.pl/Freenove-Ultimate-ESP32-S3-Dual-core-Microcontroller/dp/B0BMQ2CPQN)
- rechargable 7V – 9V battery (40 PLN, e.g. https://allegro.pl/oferta/akumulator-everactive-550mah-9v-micro-usb-li-ion-11177916518 [7.4V])
- two STM32 Nucleo boards with CAN FD interface/peripheral (2x 70 PLN, e.g. https://kamami.pl/stm-nucleo-32/575468-nucleo-g431kb-zestaw-startowy-z-mikrokontrolerem-z-rodziny-stm32-stm32g431kb-5906623436309.html)
- two CAN bus transceivers (2x 20 PLN, e.g. https://allegro.pl/listing?string=SN65HVD230)
- MOSFET H-bridge converter for a DC motor drive (20 PLN, e.g. https://allegro.pl/listing?string=TB6612FNG)
- touch screen (60 PLN, e.g. https://sklep.msalamon.pl/produkt/tft-24-spi-dotyk/)
- incremental quadrature encoder (8 PLN, e.g. https://sklep.msalamon.pl/produkt/modul-enkodera-z-przyciskiem/)
- logic-level shifter (10 PLN per 12 channels, e.g. https://sklep.msalamon.pl/produkt/konwerter-poziomow-logicznych-33v-5v-4-kanalowy/ or https://allegro.pl/listing?string=TXS0108E)

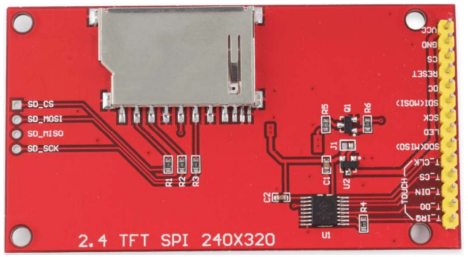
Total (after tax): ca. 120 EUR.

And again, all of the above are in my home arsenal and I’m happy with them.



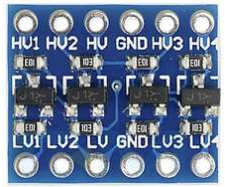














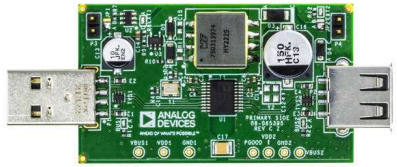
Let’s set up an electronics lab!

Yellow karate belt:

- 200 MS/s logic analyzer (800 PLN, e.g. https://kamami.pl/en/other-logic-analyzers/580100-la2016-16-channel-logic-analyzer-seeed-studio-109990065.html or https://kamami.pl/en/other-logic-analyzers/583813-dslogic-plus-16-channel-logic-analyzer.html)
- digital oscilloscope (1500 PLN, e.g. https://rigol.com.pl/pl/p/12-bit-Oscyloskop-Cyfrowy-RIGOL-DHO804-4CH-70MHz-1.25GSas-seria-DHO800/560)
- USB galvanic isolator (200 PLN, e.g. https://analogdevicesinc.github.io/documentation/solutions/reference-designs/eval-cn0550-ebz/)
- desoldering pump (40 PLN, e.g. https://allegro.pl/listing?string=yihua-929d-v)
- USB to UART converter (15 PLN, e.g. https://kamami.pl/konwertery-usb---uart--rs232/1178721-ch343-usb-uart-board-type-c-konwerter-usb-uart-z-ukladem-ch343g-5906623438907.html)

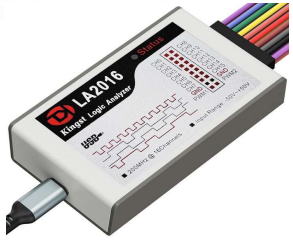












Total (after tax): ca. 600 EUR.
And again, you probably already know the drill ;)

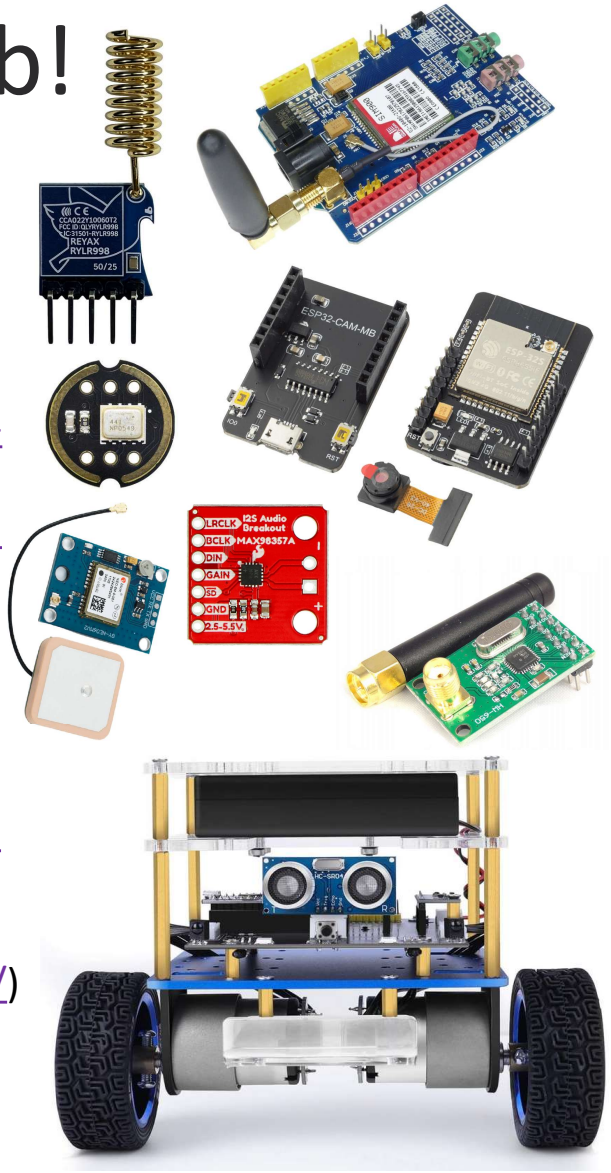
Let’s set up an electronics lab!

Yellow karate belt:

- GPS (30 PLN, e.g. https://sklep.msalamon.pl/produkt/modul-gps-gy-neo6mv2-niebieski/)
- GSM/GPRS (100 PLN, e.g. https://allegro.pl/oferta/modul-gsm-gprs-sim-900-shield-arduino-uno-antena-11816936546)
- LoRa (2x 45 PLN, e.g. https://www.amazon.com/REYAX-RYLR998-Interface-Antenna-Transceiver/dp/B099RM1XMG)
- nRF905 (2x 25 PLN, e.g. https://allegro.pl/oferta/modul-radiowy-nrf905-433-868-91mhz-transceiver-11978911141)
- camera (40 PLN, e.g. https://sklep.msalamon.pl/produkt/plytka-esp32-z-kamera-esp32-cam-wifi-ble-4-2-dedykowany-programator/)
- digital mic and decoder (20 PLN + 40 PLN, e.g. https://sklep.msalamon.pl/produkt/mikrofon-mems-wielokierunkowy-cyfrowy-inmp441/ and https://botland.store/mp3-wav-ogg-midi-players/13062-max98357a-decoder-stereo-dac-i2s-sparkfun-dev-14809-5903351249676.html)
- self-balancing robot a la Segway (420 PLN, e.g. https://www.amazon.pl/ELEGOO-samobalansuj%C4%85cy-samochodowy-kompatybilny-edukacyjna/dp/B07QVKPT6J/)

Total (after tax): ca. 160 EUR.

And again, you probably already know the drill ;)



Let’s set up an electronics lab!

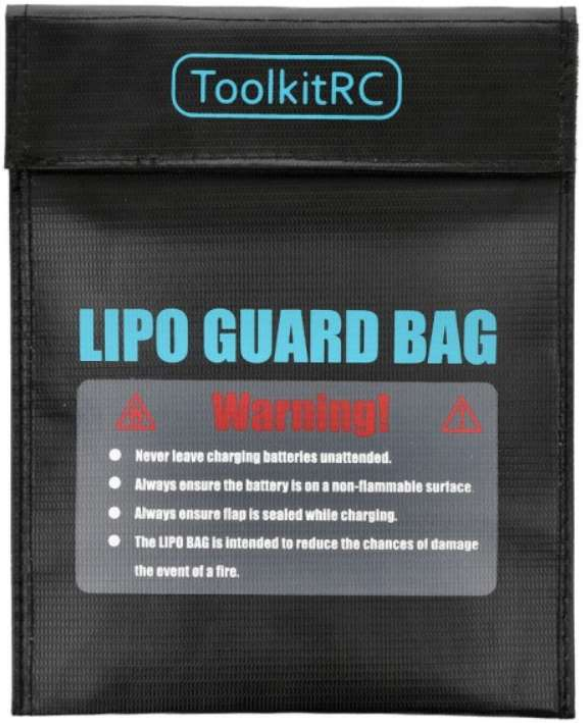
If the sky is the limit ;)

- hot air rework station (e.g. https://allegro.pl/oferta/stacja-lutownicza-hot-air-spawarka-yihua-993dm-iv-12521557906)
- soldering station with presets (e.g. https://allegro.pl/oferta/stacja-lutownicza-yihua-939d-iv-120w-900m-12537064858)
- multimeter with auto ranging (e.g. https://botland.com.pl/mierniki-uniwersalne/16717-miernik-uniwersalny-uni-t-ut33a-5901890044431.html)



And again, you probably already know the drill ;)

Safety first





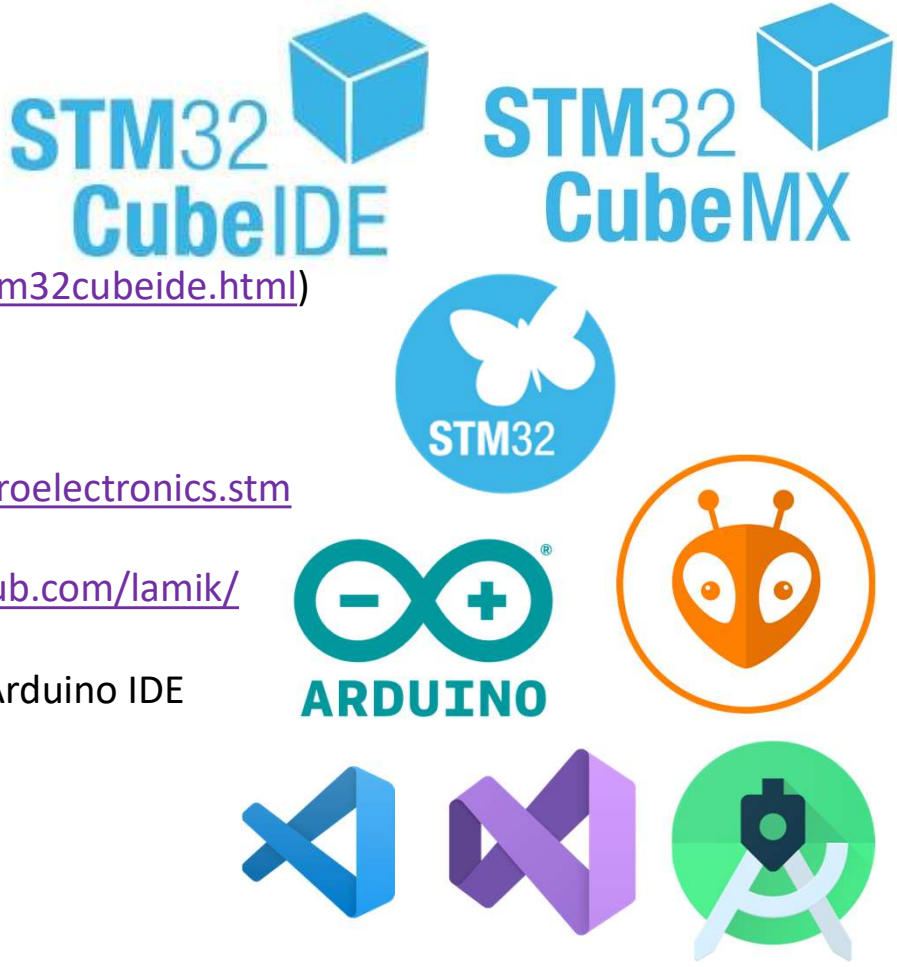


https://kamami.pl/akcesoria-do-akumulatorow/1185656-toolkitrc-lipo-safety-bag-s-pokrowiec-ochronny-do-akumulatorow-li-po-230x180mm-czarny.html
https://botland.com.pl/okulary-ochronne/22284-okulary-ochronne-z-paskiem-yato-yt-73700-5906083001314.html
https://www.kamille.pl/pl/p/Kociolek-garnek-zeliwny-mysliwski-7L/2700 (to store your batteries – it's not a joke)

Let’s set up an electronics lab!

Developement environments:

- Arduino IDE (https://www.arduino.cc/en/software)
- endless libraries and examples for e.g. ESP32 (see e.g. https://github.com/search?q=esp32&type=repositories)
- PlatformIO (https://platformio.org/)
- STM32CubeIDE (https://www.st.com/en/development-tools/stm32cubeide.html)
- STM32CubeMX2 (https://www.st.com/en/development-tools/stm32cubemx.html)
- STM32CubeIDE for Visual Studio Code (https://marketplace.visualstudio.com/items?itemName=stmicroelectronics.stm32-vscode-extension)
- endless libraries and examples for STM32 (see e.g. https://github.com/lamik/ and https://github.com/search?q=stm32&type=repositories)
- Visual Studio Code if you don’t like the editor provided by the Arduino IDE (https://code.visualstudio.com/)
- Android Studio (https://developer.android.com/studio)
- Visual Studio Community (https://visualstudio.microsoft.com/)



They are all free.

Online compilers and code sharing

Online compilers:

- OnlineGDB (https://www.onlinegdb.com/)
- Compiler Explorer (https://godbolt.org/)

Arduino simulator:

- Wokwi (https://wokwi.com/)

Git (version control system) repositories:

- GitHub (https://github.com/)
- GitLab (https://about.gitlab.com/)
- Bitbucket (https://bitbucket.org/product/)

and several more

They are all free.





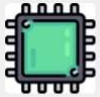








Control Engineering for Hobbyists on MS Teams



Control Engineering for Hobbyists ···

Challenge 01 (Android sensors)
Challenge 02 (H-bridge converter)
Challenge 03 (Rubik s cube solver)
Challenge 04 (Stepper motor)
Challenge 05 (Incremental encoder)
Challenge 06 (Line follower)
Challenge 07 (Holonomic platforms)
Challenge 08 (Swingbot)
Challenge 09 (Self-balancing robot)
Challenge 10 (CAN bus [Arduino])
Challenge 11 (CAN bus [STM32])
Challenge 12 (Self-balancing motorcycle)
Challenge 13 (Persistence of vision)
Challenge 14 (Word clock)
Challenge 15 (Doomsday chat)
Challenge 16 (Christmas aRGB LEDs [Arduino])
Challenge 17 (LoRa networks)
Challenge 18 (WS2812B [STM32])
Challenge 19 (USB mouse and joystick [STM32])
Challenge 20 (Thermal camera [Arduino])



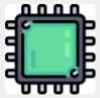
Control Engineering for Hobbyists ···

Challenge 21 (Thermal camera [STM32])
Challenge 22 (Spectrum analyser [STM32])
Challenge 23 (IR remote [Arduino])
Challenge 24 (IR remote [STM32])
Challenge 25 (nRF24L01 [STM32])
Challenge 26 (Easter eggbot)
Challenge 27 (FDCAN protocol [STM32])
Challenge 28 (Reaction wheel)
Challenge 29 (Tensometric sensors, load cell)
Challenge 30 (Drone)
Challenge 31 (nRF905 [STM32])
Challenge 32 (MPU6050, Kalman filter [STM32])
Challenge 33 (XPT2046 touch screen)
Challenge 34 (AI)
Challenge 35 (Robot vision [Pixy2])
Challenge 36 (Mass storage, USB, SDIO [STM32])
Challenge 37 (Gesture sensor [STM32])
Challenge 38 (I2C multiplexer [STM32])
Challenge 39 (Multiple servos, PCA9685 [STM32])
Challenge 40 (GPS receiver [STM32])



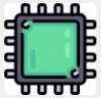
Control Engineering for Hobbyists ···

Challenge 41 (1-Wire, DS18B20 temp. sensor)
Challenge 42 (GSM, GPRS, SMS, SIM800L [STM32])
Challenge 43 (FSMC TFT ILI9341)
Challenge 44 (OV7670 camera sensor)
Challenge 45 (The Game of Life)
Challenge 46 (Useless machine)
Challenge 47 (PCB design, KiCad)
Challenge 48 (I2S microphone)
Challenge 49 (OV2640 camera sensor)
Challenge 50 (I2S WAV player)
Challenge 51 (Weather station [STM32])
Challenge 52 (Ethernet [STM32, ESP32])
Challenge 53 (MP3 player [STM32])
Challenge 54 (WAV recorder [STM32])
Challenge 55 (Submarine)
Challenge 56 (NTP)
Challenge 57 (USB keyboard [STM32])
Challenge 58 (Web server [ESP32])
Challenge 59 (Ultrasonic sensors [STM32])
Challenge 60 (ICM-20948 9DoF motion sensor)
Challenge 61 (3D graphics)



Control Engineering for Hobbyists ···

Challenge 62 (3D acoustic vector sensor)
Challenge 63 (Optical tachometer)
Challenge 64 (Menu)
Challenge 65 (Smartwatch)
Challenge 66 (Barometer, altimeter)
Challenge 67 (FM tuner)
Challenge 68 (External EEPROM and flash)
Challenge 69 (TOF laser range sensor [CAN bus])
Challenge 70 (ESP-NOW protocol)
Challenge 71 (STM32CubeIDE vs. Arduino IDE)
Challenge 72 (Fluid level meter)
Challenge 73 (USB composite)
Challenge 74 (MLX90614 pyrometer)
Challenge 75 (GPS receiver and Kalman filter)
Challenge 76 (ESP32 can CAN!)
Challenge 77 (AM radio transmitter)
Challenge 78 (Time lapse)
Challenge 79 (Audio signal processing)
Challenge 80 (Hysteresis control)
Challenge 81 (Peltier effect cooling)



Control Engineering for Hobbyists ···

Challenge 107 (DIY oscilloscope)
Challenge 108 (Servo drive, half-duplex UART)
Challenge 109 (Quick Charge 3.0)
Challenge 110 (USB Power Delivery)
Challenge 111 (FPGA)
Challenge 112 (Inductive heating)
Challenge 113 (Capacitive touch sensing)
Challenge 114 (PS3 controller)
Challenge 115 (Bootloader)
Challenge 116 (Buck-boost converter)
Challenge 117 (Tesla coil)
Challenge 118 (Metal detector)
Challenge 119 (CANopen [STM32])
Challenge 120 (Air quality)
Challenge 121 (Ucap vs. coin cell for RTC)
Challenge 122 (CAN TP)
Challenge 123 (Airplane)
Challenge 124 (OpenCV)
Challenge 125 (BLE HMI on MCU [Arduino])
Challenge 126 (BLE terminal [STM32])

Join us!

Control Engineering for Hobbyists on MS Teams (cont.)



Control Engineering for Hobbyists

- Challenge 126 (BLE terminal [STM32])
- Challenge 127 (Hardware CRC)
- Challenge 128 (Op-amps)
- Challenge 129 (ST-LINK)
- Challenge 130 (NanoVNA)
- Challenge 131 (Debug mode in Arduino)
- Challenge 132 (eFuses and ideal diodes)
- Challenge 133 (Balancing with propellers)
- Challenge 134 (PWM and ADC synchronization)
- Challenge 135 (DWIN HMI)
- Challenge 136 (UV sensor)
- Challenge 137 (Odometry)
- Challenge 138 (String art)
- Challenge 139 (Laser engraver)
- Challenge 140 (CNC mill)
- Challenge 141 (Lightning sensor)
- Challenge 142 (Capacitive soil moisture sensor)
- Challenge 143 (UWB indoor localization)
- Challenge 144 (Zigbee [ESP32-C6])
- Challenge 145 (MQTT [ESP32])



Control Engineering for Hobbyists

- Challenge 146 (I2C slave [STM32])
- Challenge 147 (Roll a die with Charlie [STM32])
- Challenge 148 (External flash memory [STM32])
- Challenge 149 (DShot ESC protocol [STM32])
- Challenge 150 (DCF77 and e-CzasPL radio clocks)
- Challenge 151 (TRNG using Geiger-Muller tube)
- Challenge 152 (Energy harvester)
- Challenge 153 (Tire pressure monitor system)
- Challenge 154 (Laser projector)
- Challenge 155 (Projection clock)
- Challenge 156 (STM32 overclocking)
- Challenge 157 (FRAM [MSP430FR])
- Challenge 158 (VFD, nixie tubes [retro, vintage])
- Challenge 159 (LIN bus)
- Challenge 160 (Motor Control Workbench)
- Challenge 161 (Flapping drone)
- Challenge 162 (VGA signal [STM32])
- Challenge 163 (LoRa and LoRaWAN GPS trackers)
- Challenge 164 (Energia IDE or not [TI MCP])
- Challenge 165 (Processing IDE)



Control Engineering for Hobbyists

- Challenge 166 (CAN XL)
- Challenge 167 (HIL simulation)
- Challenge 168 (Isolated SPI, CAN or I2C)
- Challenge 169 (Acoustic levitation)
- Challenge 170 (DLP projector)
- Challenge 171 (Dual-core uC data sharing [STM3...
- Challenge 172 (EMI, EMC)
- Challenge 173 (Nissan Note hacking)
- Challenge 174 (Car dashboard instrument cluster)
- Challenge 175 (Softstart)
- Challenge 176 (Speaking calipers)
- Challenge 177 (OBD-II digital instrument cluster)
- Challenge 178 (Password hashing, EEPROM)
- Challenge 179 (CPU load monitor [STM32])
- Challenge 180 (Cryptographic library)
- Challenge 181 (ATtiny for budget projects)
- Challenge 182 (State machine)
- Challenge 183 (MCP9808 and STM32CubeMonitor)
- Challenge 184 (Monocopter)
- Challenge 185 (FlexRay, MOST)



Control Engineering for Hobbyists

- Challenge 186 (FOC)
- Challenge 187 (Next level car hacking)
- Challenge 188 (SLCAN protocol)
- Challenge 189 (OCPP)
- Challenge 190 (Drone propeller test rig)
- Challenge 191 (USB I2S microphone)
- Challenge 192 (Home Assistant)
- Challenge 193 (QEP, SPI and SSI encoders)
- Challenge 194 (Fair dice tester)
- Challenge 195 (STS3215 and DDSM400 servo dri...
- Challenge 196 (OV5640 camera with AF)
- Challenge 197 (WiFi and BLE AT via UART for ST...
- Challenge 198 (SCPI)
- Challenge 199 (ChatGPT)
- Challenge 200 (CAN bus and LIN bus security)
- Challenge 201 (Zephyr RTOS)
- Challenge 202 (AM32 ESC firmware and 1-DOF c...
- Challenge 203 (Qt)
- Challenge 204 (Throttle body)
- Challenge 205 (Coolant circulation pump)



Control Engineering for Hobbyists

- Challenge 206 (Multifunction steering wheel)
- Challenge 207 (Heater blower fan motor drive)
- Challenge 208 (Voice recognition)
- Challenge 209 (4-pin computer fan)
- Challenge 210 (SMBus I2C notebook battery)
- Challenge 211 (Adjustable foldable wing mirrors)
- Challenge 212 (T-Rex Game runner)
- Challenge 213 (Headlight leveling servo)
- Challenge 214 (iDrive knob and haptic touchpad)
- Challenge 215 (LIN-n-Clock)
- Challenge 216 (Single-wire CAN bus)
- Challenge 217 (USB Host HID mouse and keyboa...
- Challenge 218 (Window lift drive)
- Challenge 219 (Rear wiper actuator)
- Challenge 220 (Tailgate pull-down motor)
- Challenge 221 (Rain sensor)
- Challenge 222 (YoRadio)
- Challenge 223 (ISOBUS)
- Courses at WUT
- Critical thinking skills

Join us!

All set and done! But where to start?

"It takes half your life before you discover life is a do-it-yourself project." Napoleon Hill

https://medium.com/@nancy.e.huang/life-is-a-do-it-yourself-project-d131c4b82340

- Just pick a DIY project that you would like to brag about and do it, and then brag about it!
- Be inspired by other DIY projects. Check them out e.g. on YT, Instructables, Arduino Project Hub, How 2 Electronics, Circuit Digest, Hackaday – these are just examples as this comunity is enormous, and thats good for us! Some of my favorite YT creators regarding STM32/ESP32 DIY projects are: Phil's Lab, Controllers Tech, DroneBot Workshop, and Andreas Spiess.
- „It is the time you have wasted for your rose that makes your rose so important." – Antoine de Saint-Exupéry, The Little Prince. So maybe start from building a clock ;)









Learning resources

Tutorials, examples and libraries provided by the DIY industry. Some of my favorite ones are:

- https://www.adafruit.com/
- https://www.waveshare.com/
- https://www.sparkfun.com/
- https://www.dfrobot.com/
- https://www.freenove.com/
- https://www.elegoo.com/
- https://www.upesy.com/

Some DIY stores and training providers offer their own knowledge bases for free. Some of my favorite ones are unfortunately available only in Polish (fortunately, the C/C++ code itself is a universal language):

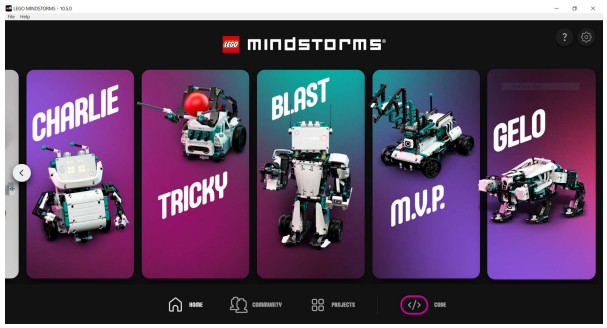
- https://forbot.pl/blog/kursy
- https://msalamon.pl/
- https://ucgosu.pl/
- https://intertechacademy.pl/
- https://www.kursyautomotive.pl/

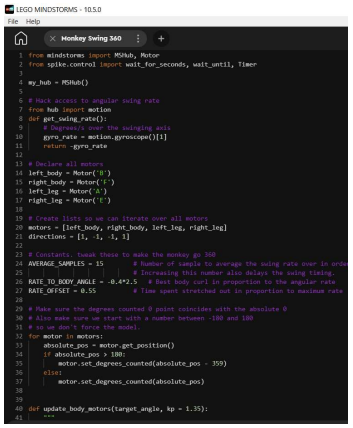
And last but not least – the communities around chip manufacturers itself, for example:

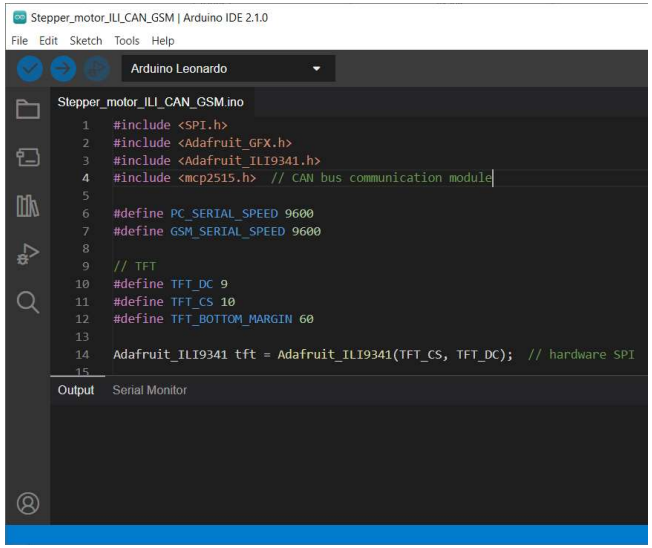
- https://community.st.com/

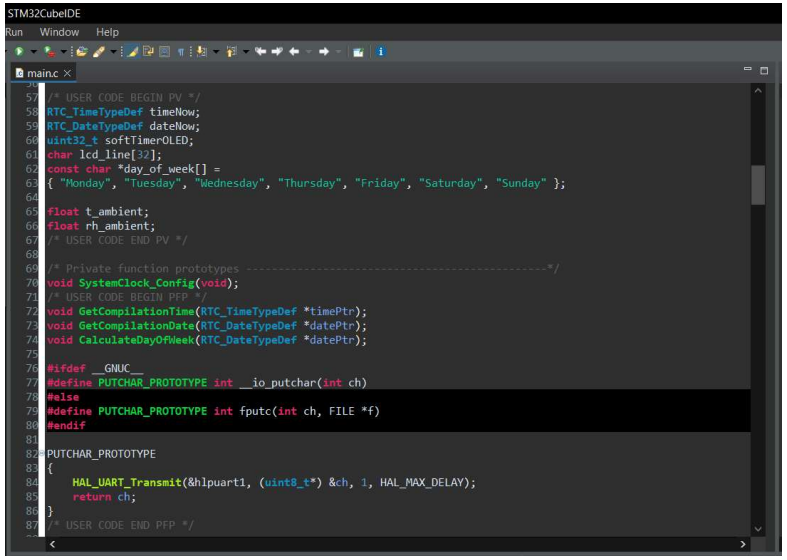
A typical learning path or an atypical one?

LEGO → Arduino IDE → STM32CubeIDE or TI CCS IDE or many others



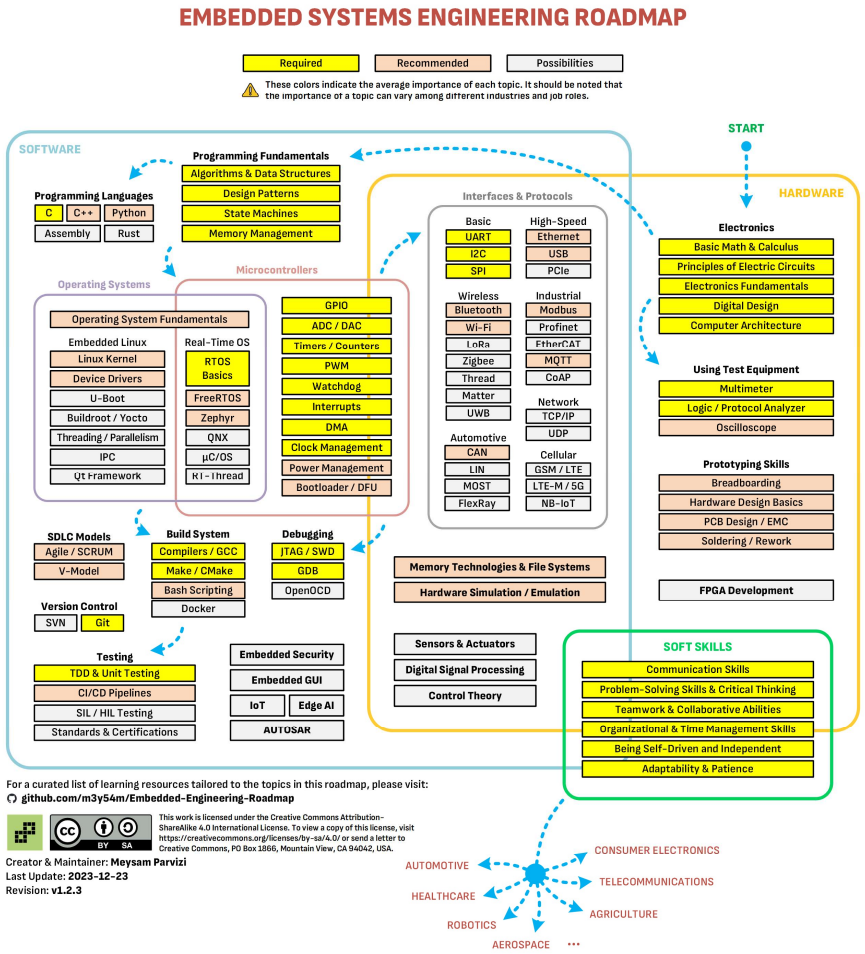






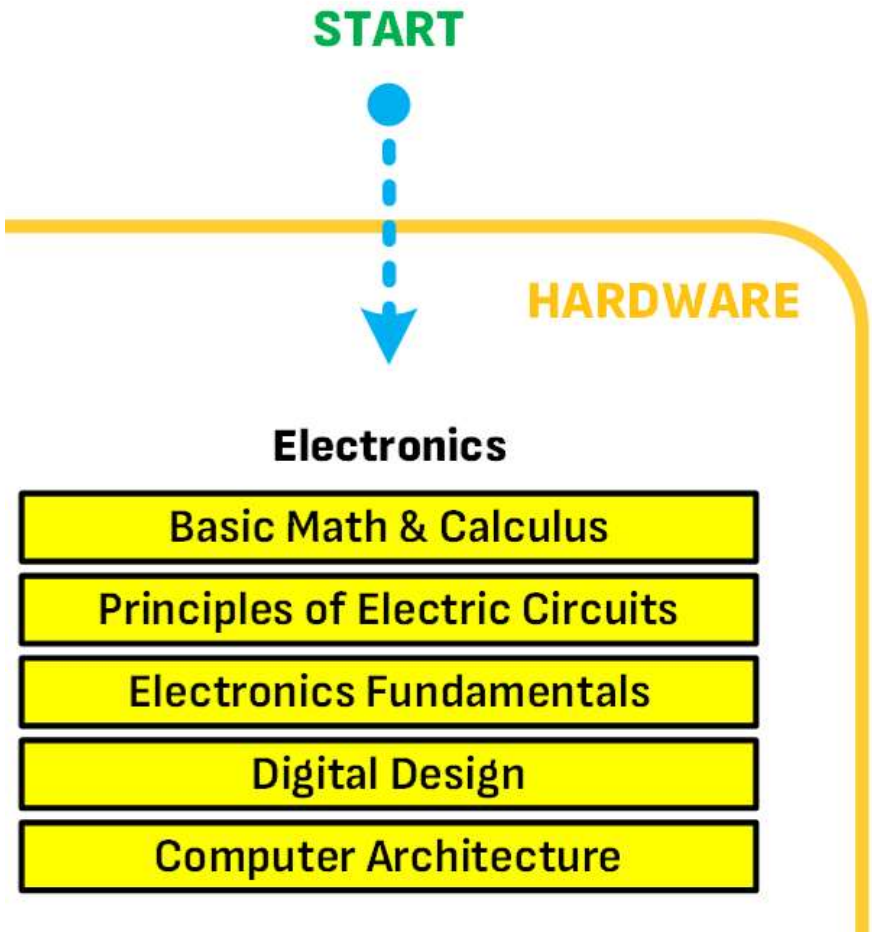
https://www.youtube.com/watch?v=tvLhI2XX9Vs

Embedded Systems Engineering Roadmap

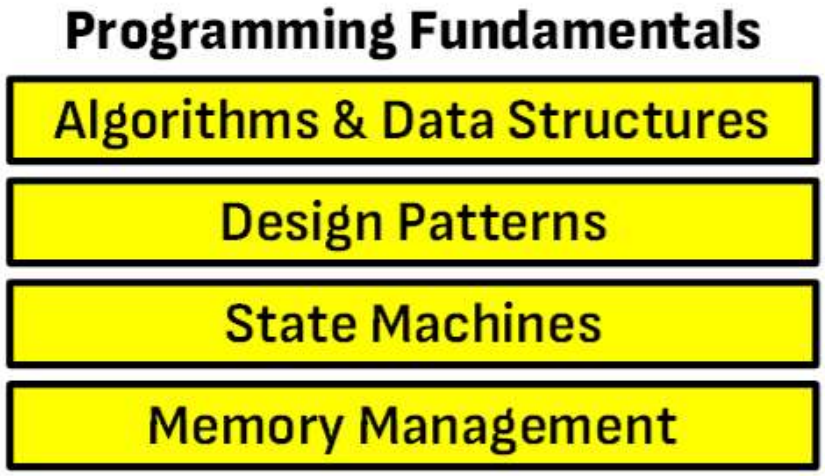


https://github.com/m3y54m/Embedded-Engineering-Roadmap

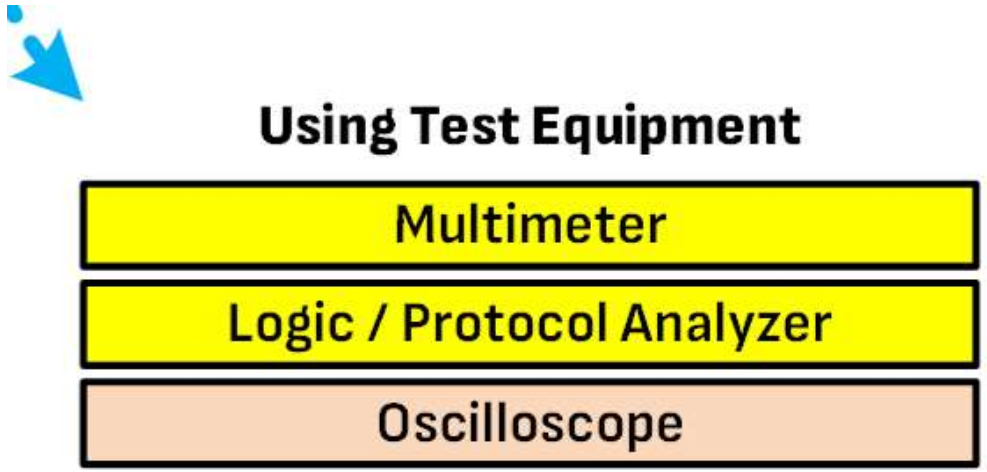
Embedded Systems Engineering Roadmap



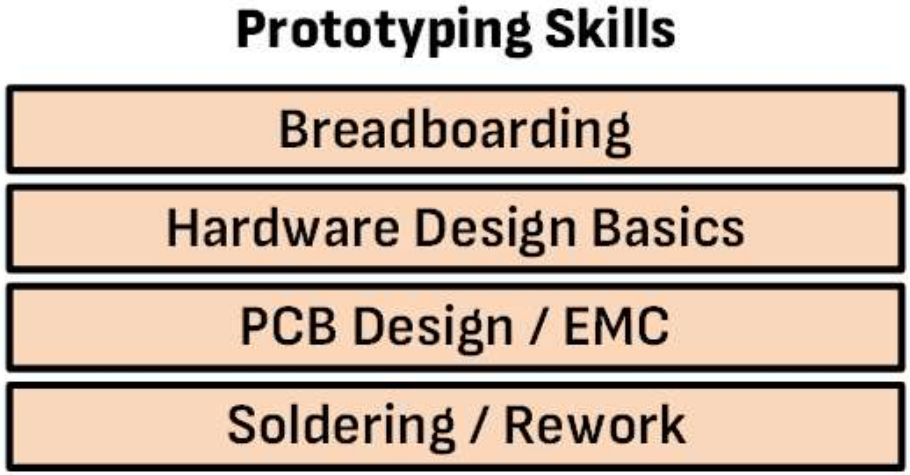
Embedded Systems Engineering Roadmap



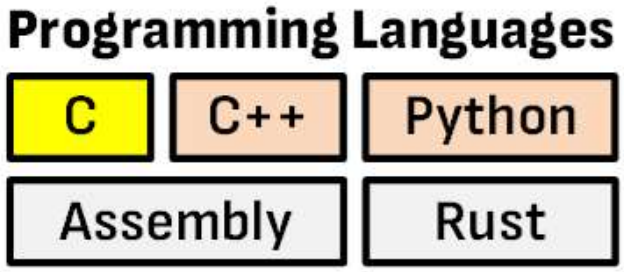
Embedded Systems Engineering Roadmap



Embedded Systems Engineering Roadmap



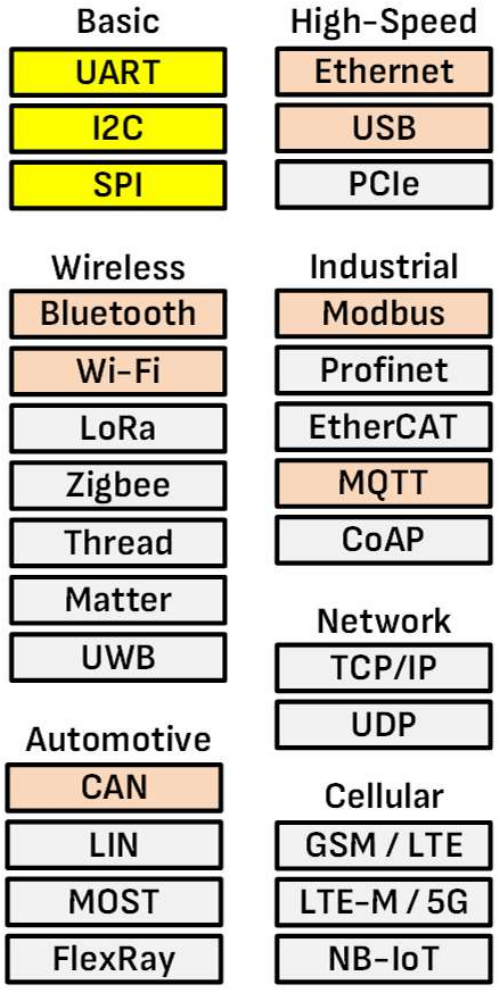
Embedded Systems Engineering Roadmap



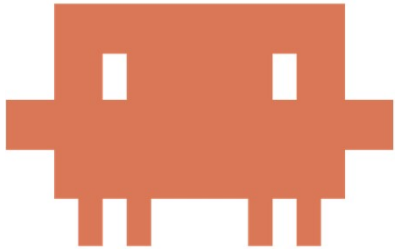
Embedded Systems Engineering Roadmap



Embedded Systems Engineering Roadmap



AI in Embedded





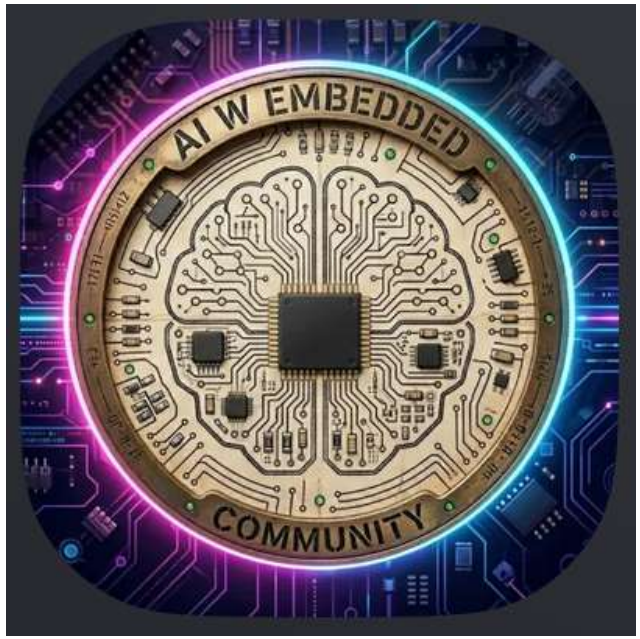


https://www.anthropic.com/product/claude-code

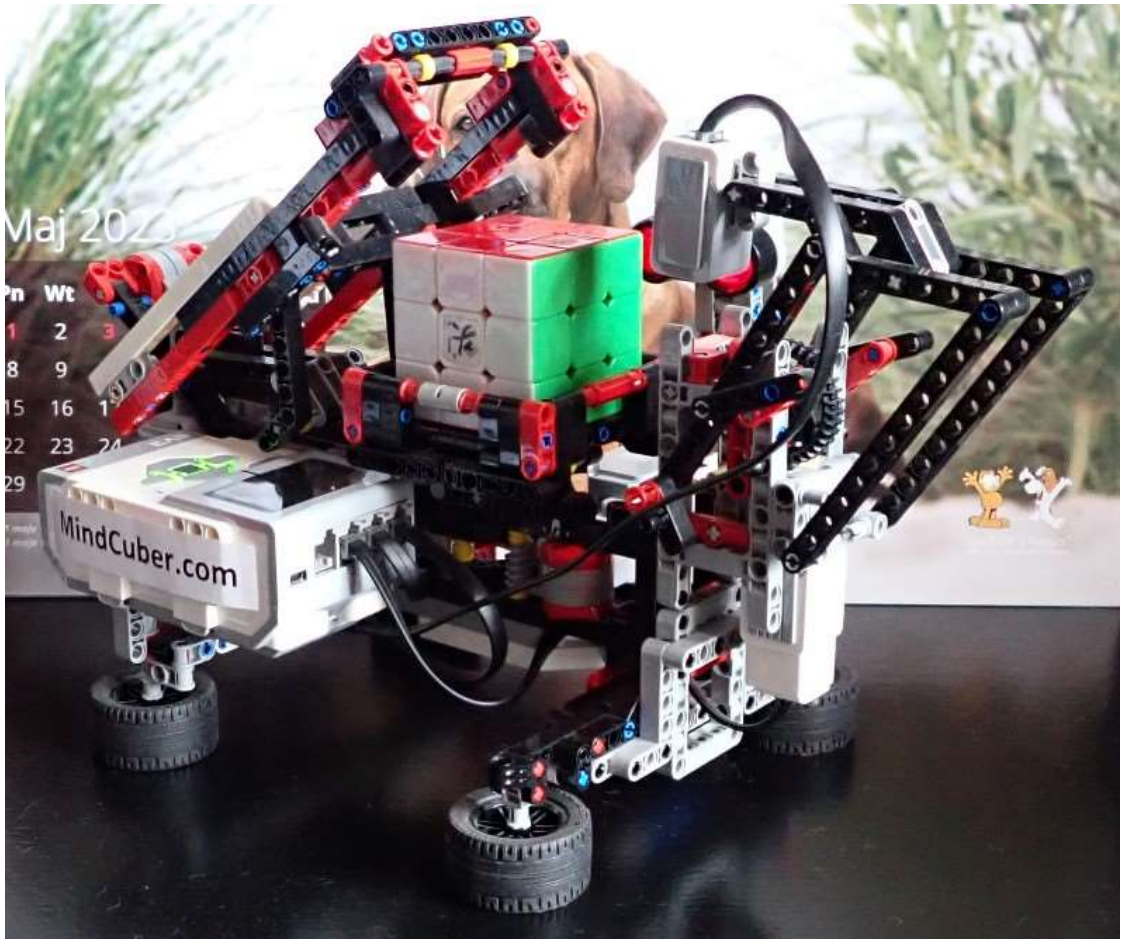
https://openai.com/codex/

https://github.com/features/copilot

A community of early adopters and early majority:
https://linki.msalamon.pl/ai_embedded



Let’s solve something! [Demo 1/8]



Exemplary hardware and software

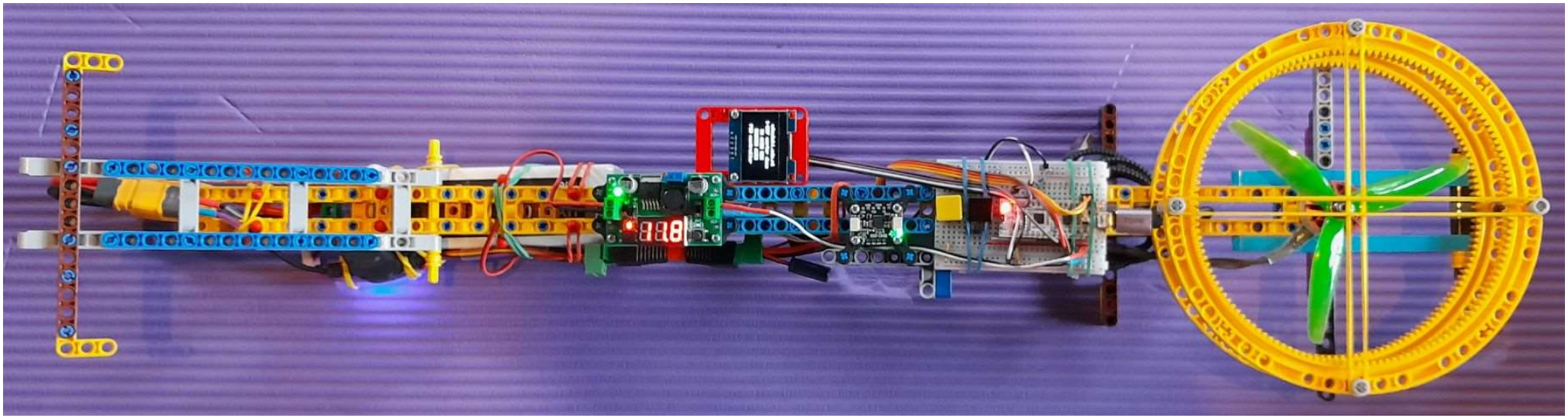
- Hardware: e.g. LEGO Mindstorms 51515 (2500 PLN)
- IDE: LEGO Mindstorms
- Code: https://mindcuber.com/

Not the cheapest one but a great educational tool – especially when you have younger siblings. Extremely fast prototyping of the mechanical part of your projects.





Let’s spin at 20 000 rpm! [Demo 2/8]



https://github.com/ufnalski/one_dof_copter_bno055_l432kc

Exemplary hardware and software

- Hardware: an ESC (electronic speed controller) supporting DShot (40 PLN), any microcontroller capable of PWM at 300 kHz with a resolution of ca. 100, i.e. clocked at 30+ MHz, here Nucleo-L432KC is used (60 PLN), a BLDC motor (75 PLN), an IMU (starting from 15 PLN), a Li-pol battery capable of ca. 15 A (40 PLN)
- IDE: STM32CubeIDE, as the microcontroller is STM32L432KC
- Code: https://github.com/ufnalski/one_dof_copter_bno055_l432kc

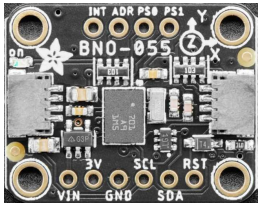










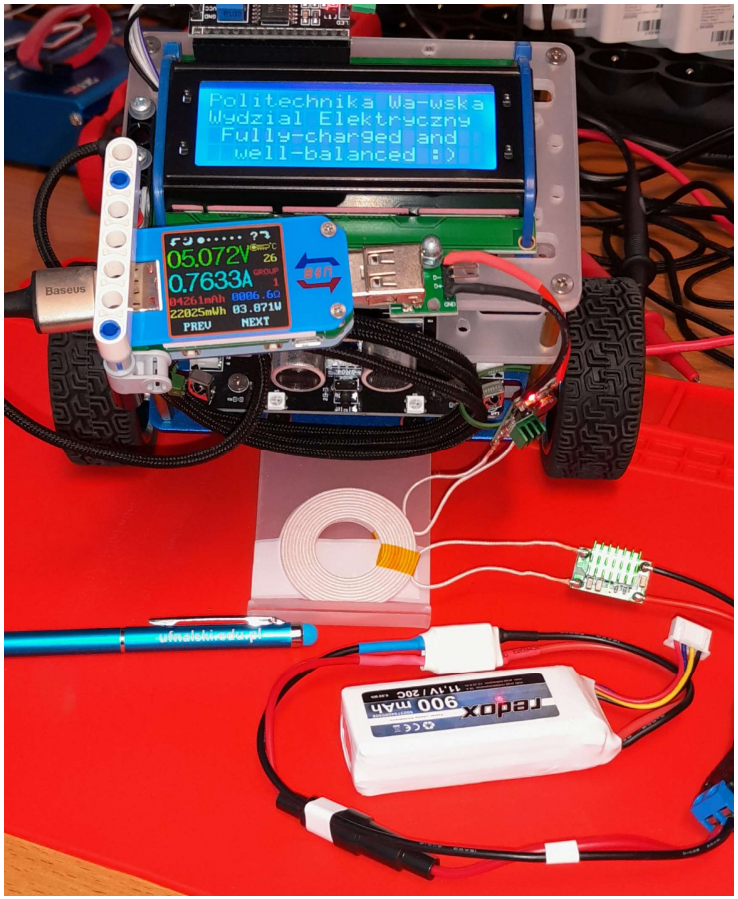




https://learn.adafruit.com/adafruit-bno055-absolute-orientation-sensor
https://allegro.pl/oferta/smigla-hqprop-ethix-s4-lemon-lime-12257543294
https://allegro.pl/oferta/silnik-t-motor-velox-veloce-v2306-v2-1950kv-12220375806
https://megadron.pl/pl/products/akumulator-gens-ace-soaring-1000mah-11-1v-30c-3s1p-xt60-25080.html
https://kamami.pl/sterowniki-silnikow-bezszczotkowych-bldc/1187457-skystars-talon32-40a-sterownik-esc-silnikow-bezszczotkowych-40a-3-6s-blheli-32-5906623465439.html

Let’s keep some balance and charge our batteries!

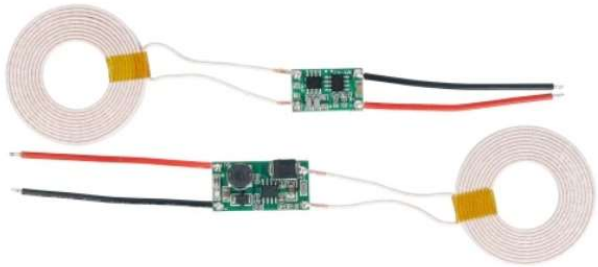
[Demo 3/8]



Exemplary hardware and software

[BOM = a bill of materials]

- Hardware: a USB tester (110 PLN), a wireless/contactless charging module (50 PLN), an LCD display with I2C interface (30 PLN), ELEGOO Tumbller self-balancing robot (400 PLN)
- IDE: VS Code + PlatformIO (Arduino framework)
- Exemplary code: http://ufnalski.edu.pl/control_engineering_for_hobbyists/2024_dzien_otwarty_we/



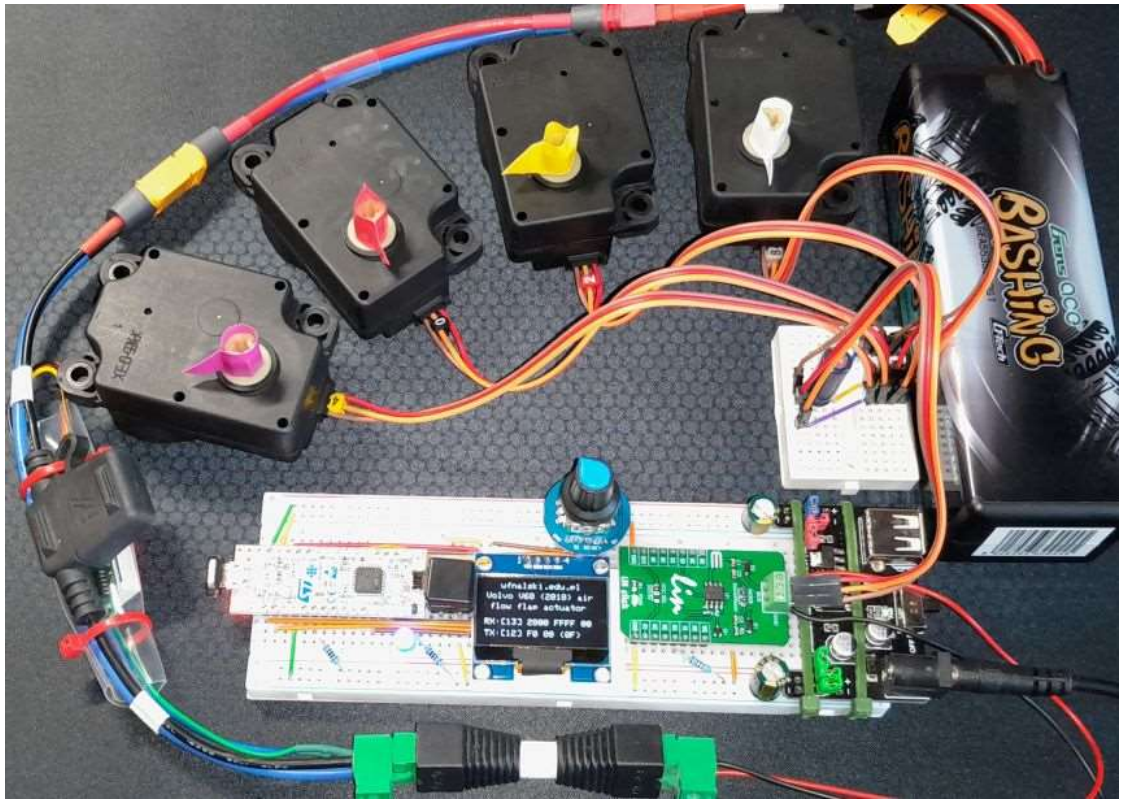






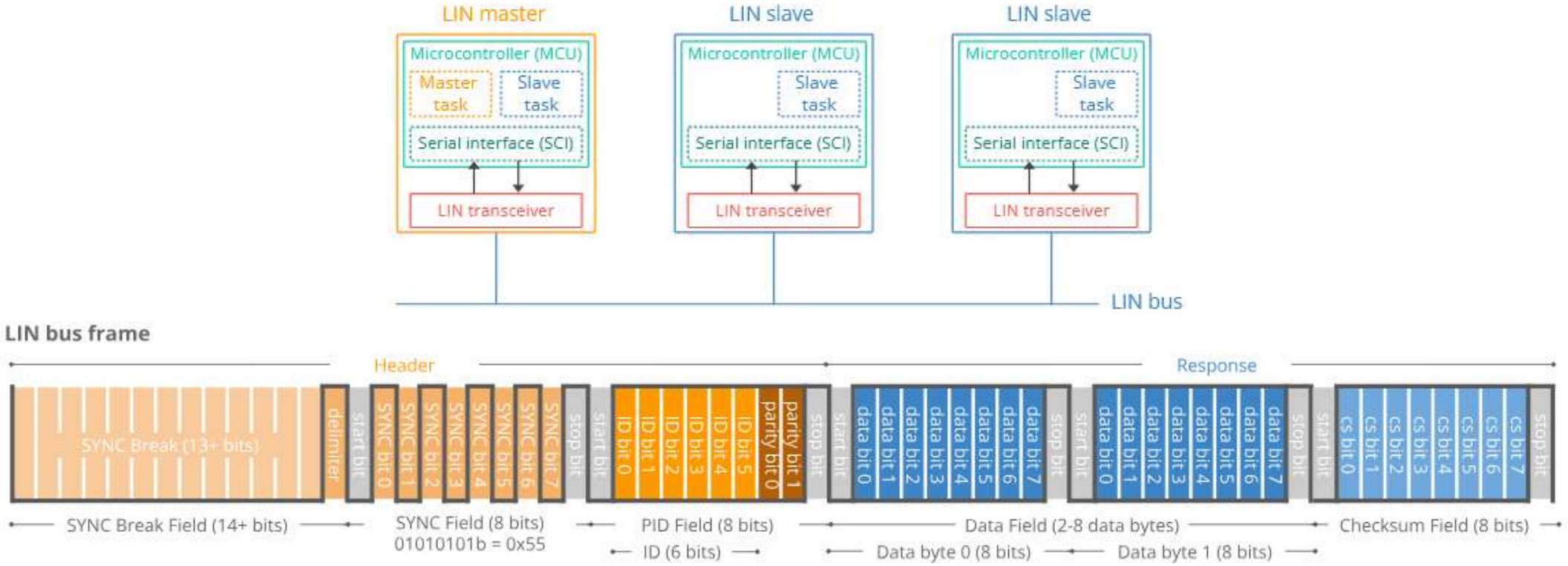
https://www.dfrobot.com/product-2105.html
https://kamami.pl/testery-usb/582402-um25-wielofunkcyjny-tester-usb.html
https://www.amazon.pl/AZDelivery-HD44780-interfejsem-kompatybilny-Raspberry/dp/B07DDGNPX1
https://www.amazon.pl/ELEGOO-samobalansuj%C4%85cy-samochodowy-kompatybilny-edukacyjna/dp/B07QVKPT6J
https://www.elegoo.com/blogs/arduino-projects/elegoo-tumbller-self-balancing-robot-car-tutorial

A step in the right direction! [Demo 4/8]



https://github.com/ufnalski/volvo_v60_air_flow_flap_actuator_g431kb

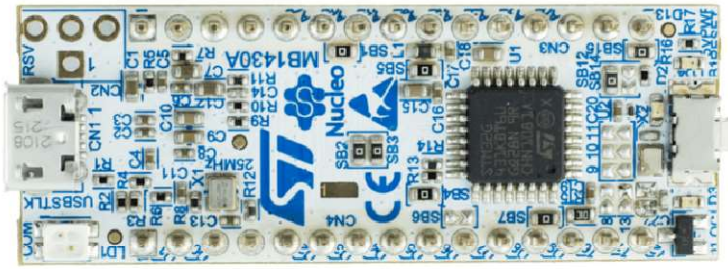
LIN bus in automotive



https://www.csselectronics.com/pages/lin-bus-protocol-intro-basics

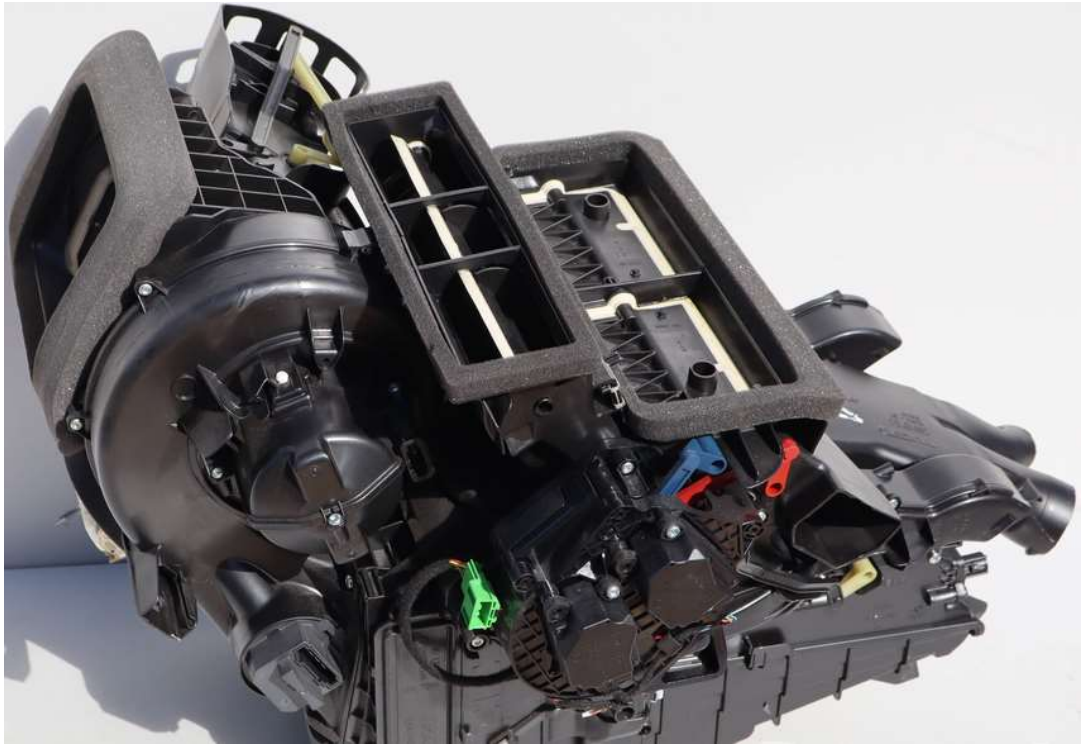
Exemplary hardware and software

- Hardware: Volvo V60 (2010+) air flow flap servo drives (pre-owned ones start at 10 PLN per piece), any microcontroller capable of UART, i.e. any uC out there (Nucleo STM32 boards start from 60 PLN), a LIN transceiver evalboard (ca. 50 PLN)
- Exemplary code: https://github.com/ufnalski/volvo_v60_air_flow_flap_actuator_g431kb

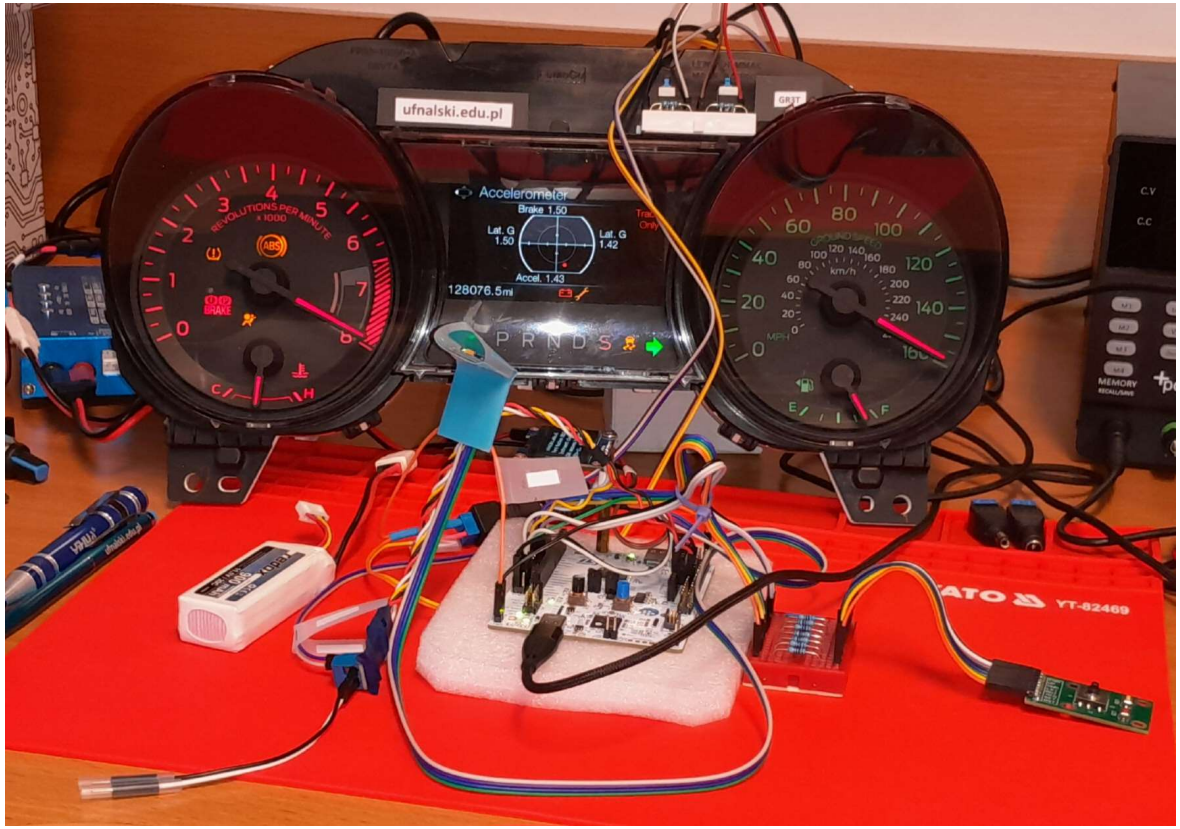




https://www.mikroe.com/lin-click
https://allegro.pl/listing?string=6G9N19E616
https://kamami.pl/stm-nucleo-32/572912-nucleo-l412kb-zestaw-startowy-z-mikrokontrolerem-stm32l412kb-5906623410392.html

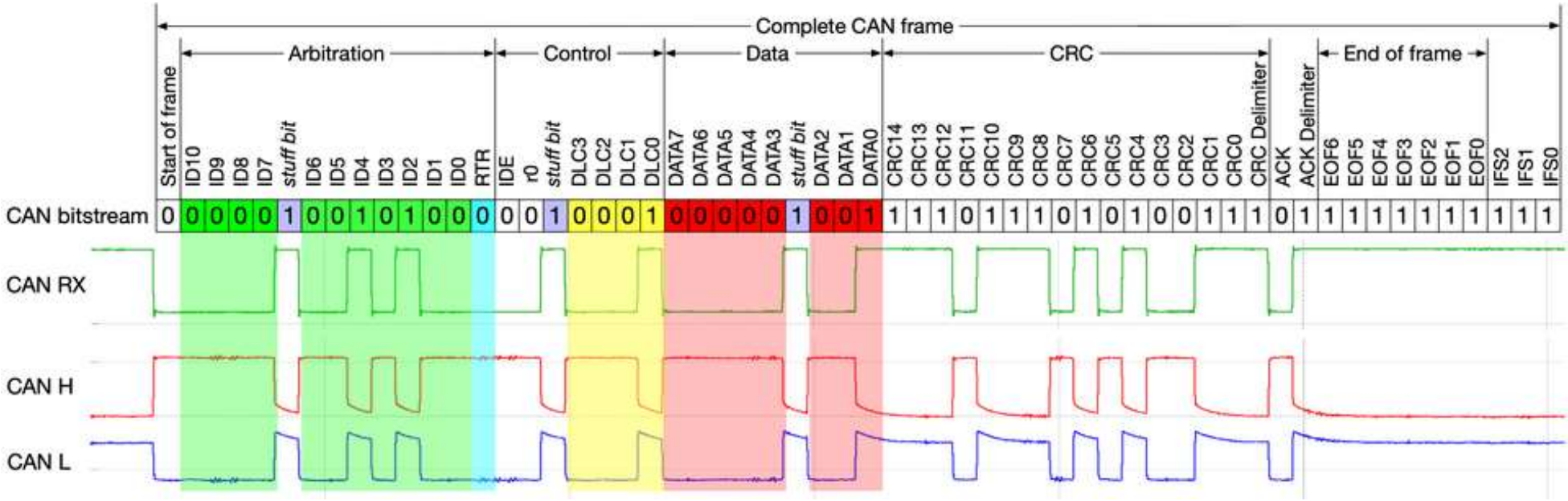


Let’s hack some instrument cluster and accelerate to the limit! [Demo 5/8]



https://github.com/ufnalski/ford_mustang_cluster_h503rb

CAN bus in automotive

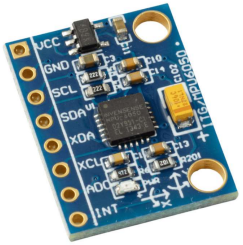


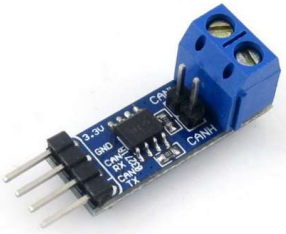
https://en.wikipedia.org/wiki/CAN_bus
https://www.csselectronics.com/pages/can-bus-simple-intro-tutorial

Exemplary hardware and software

[BOM = a bill of materials]

- Hardware: any microcontroller capable of CAN 2.0B, here Nucleo-H503RB is used (80 PLN), a CAN bus transceiver, e.g. Waveshare SN65HVD230 CAN evaluation board (20 PLN), the sixth-generation Ford Mustang (S550) used instrument panel cluster (100 PLN)
- IDE: STM32CubeIDE, as the microcontroller is STM32H503RB
- Exemplary code: https://github.com/ufnalski/ford_mustang_cluster_h503rb





CAN





https://www.waveshare.com/wiki/SN65HVD230_CAN_Board
https://www.st.com/en/evaluation-tools/nucleo-h503rb.html
https://www.youtube.com/watch?v=OzUs28GIq0A
https://sklep.msalamon.pl/produkt/mpu6050-modul/
https://kamami.pl/konwertery-can/569521-waveshare-modul-interfejsu-can-sn65hvd230.html

Action plan: connect it to your favourite simulator!





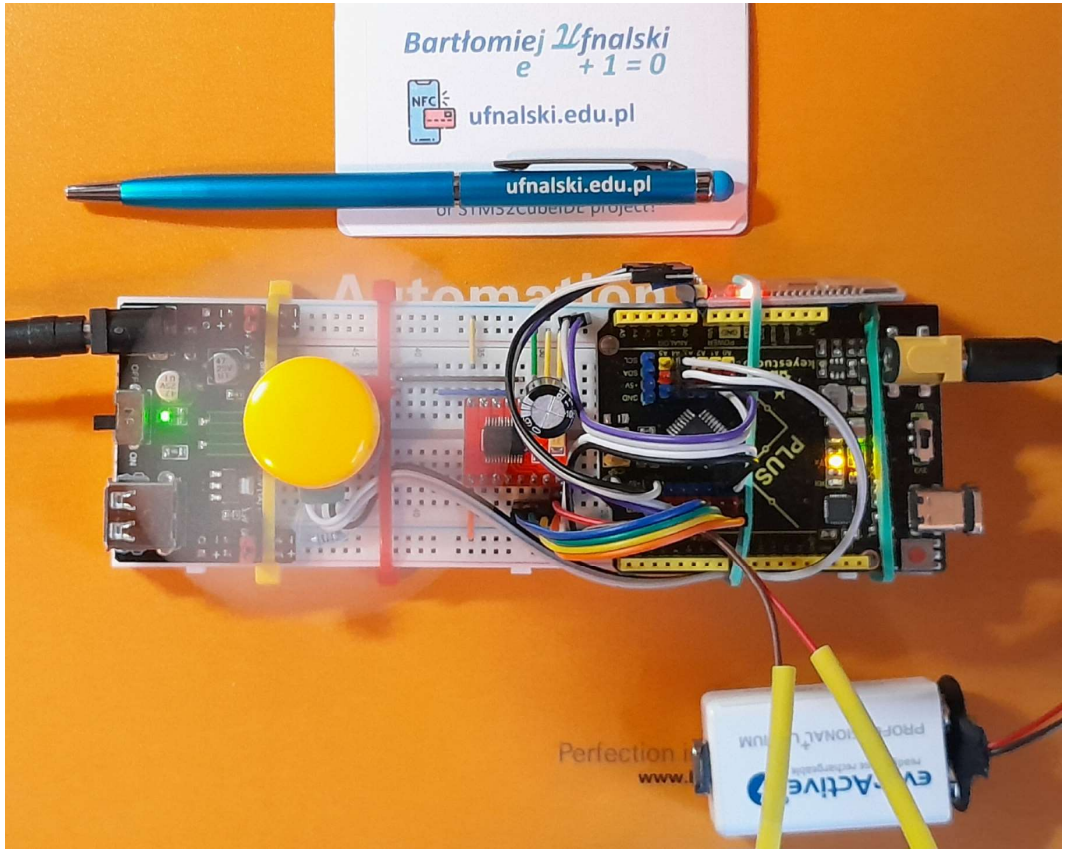
https://www.simhubdash.com/
https://www.youtube.com/@MattechPC
https://www.youtube.com/watch?v=mzjBLN_IS14

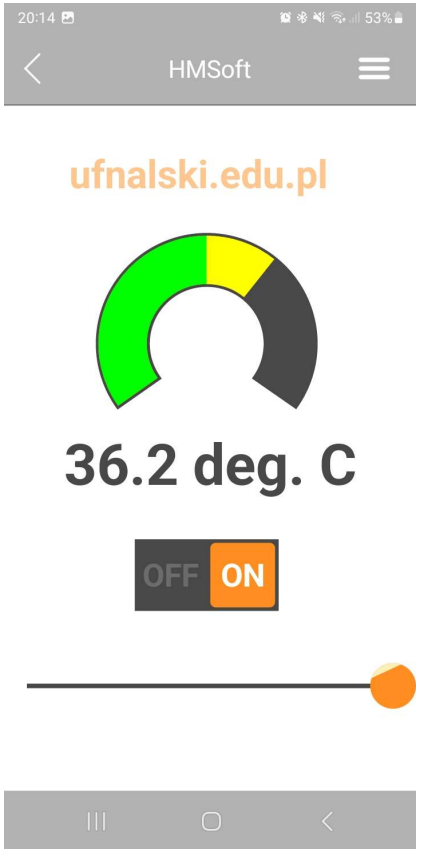
MATTECH

SimHub

Let’s use your phone to access an electric drive!

[Demo 6/8]

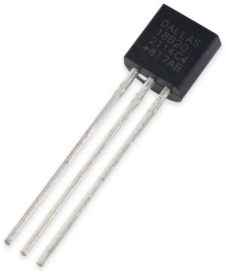




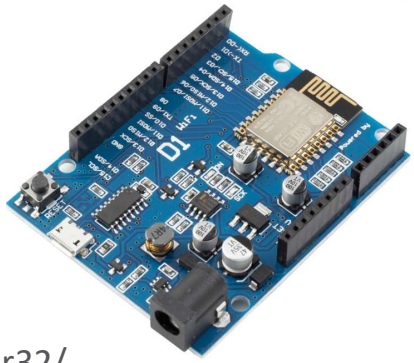
Exemplary hardware and software

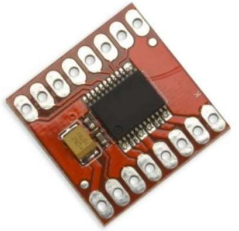
- Hardware: some DC motor with a power electronic converter (20 PLN), any microcontroller with an UART interface and at least one PWM capable GPIO, so basically any microcontroller already mentioned, e.g. ESP8266 (20 PLN), a BLE module (20 PLN), a temperature sensor (5 PLN)
- IDE: Arduino and https://remotexy.com/
- Code: http://ufnalski.edu.pl/control_engineering_for_hobbyists/2024_dzien_otwarty_we/

Bluetooth plays a big part in the short-range wireless connectivity of our devices – it's an excellent addition to your projects.











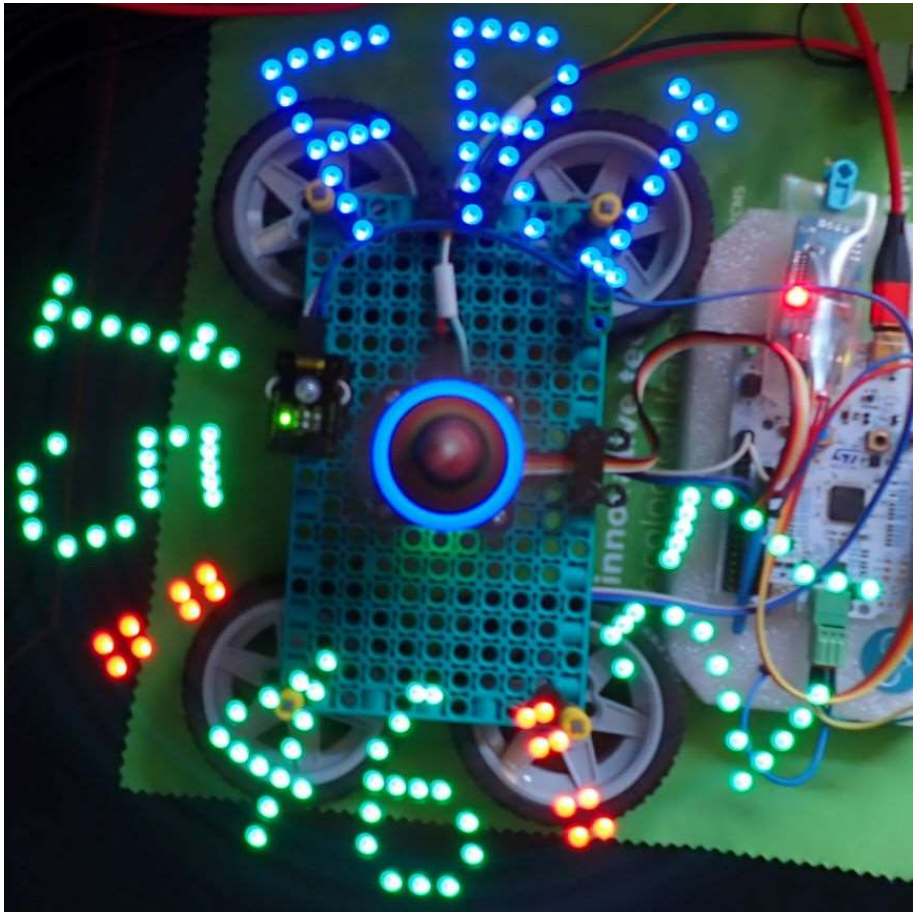
https://sklep.msalamon.pl/produkt/esp32-wemos-d1-uno-r32/
https://sklep.msalamon.pl/produkt/czujnik-temperatury-ds18b20/
https://www.amazon.pl/DSD-TECH-Bluetooth-iBeacon-Arduino/dp/B06WGZB2N4/
https://allegro.pl/oferta/sterownik-silnika-drv8833-2-kanalowy-czerwony-9567349417
https://botland.com.pl/silniki-dc-katowe-z-przekladnia/3696-kolo-silnik-65x26mm-5v-z-przekladnia-48-1-5903351248129.html

Now it’s your turn to turn the electric drive!



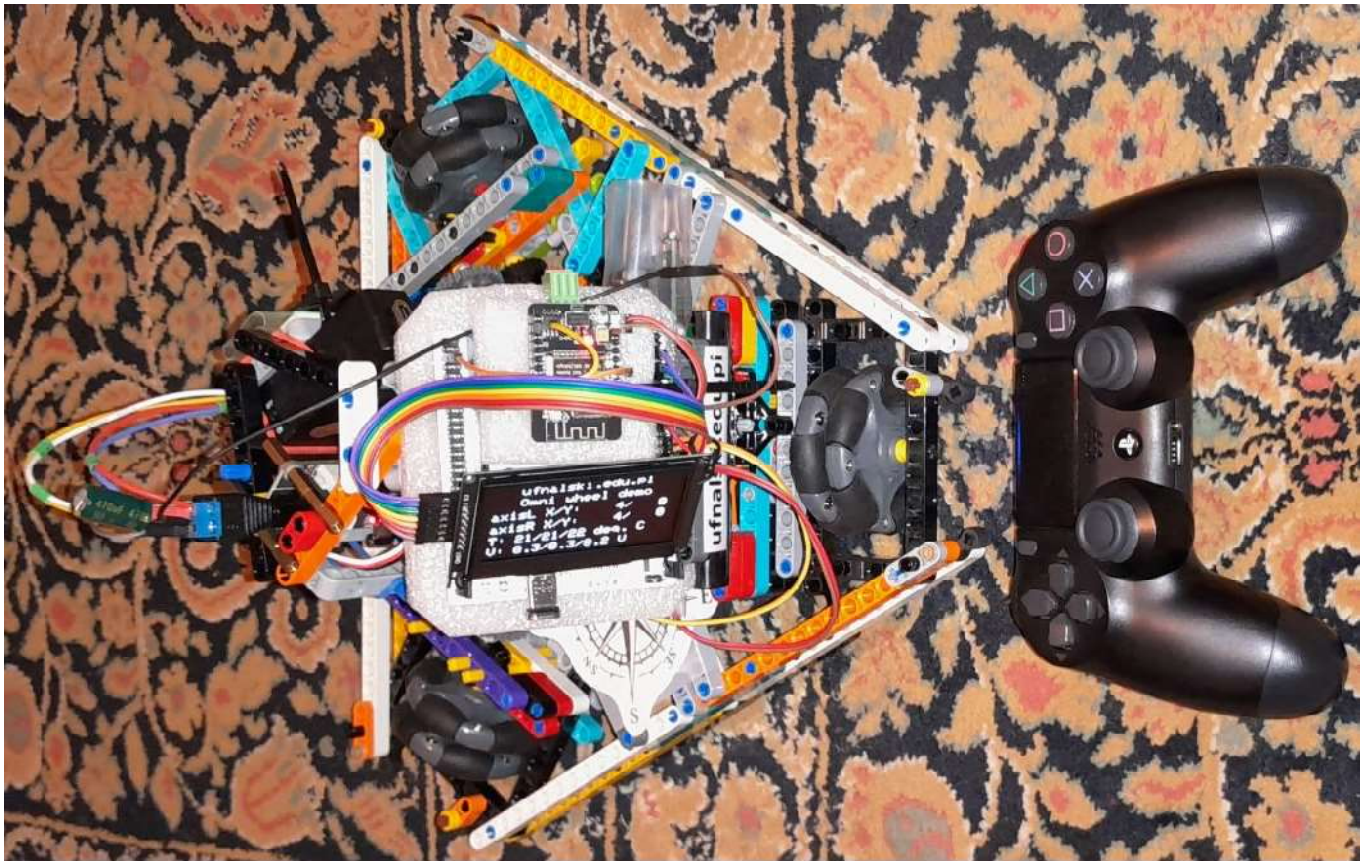
https://play.google.com/store/apps/details?id=com.shevauto.remotexy.free
https://qr.io/

Persistence of vision (POV) clock [Demo 7/8]



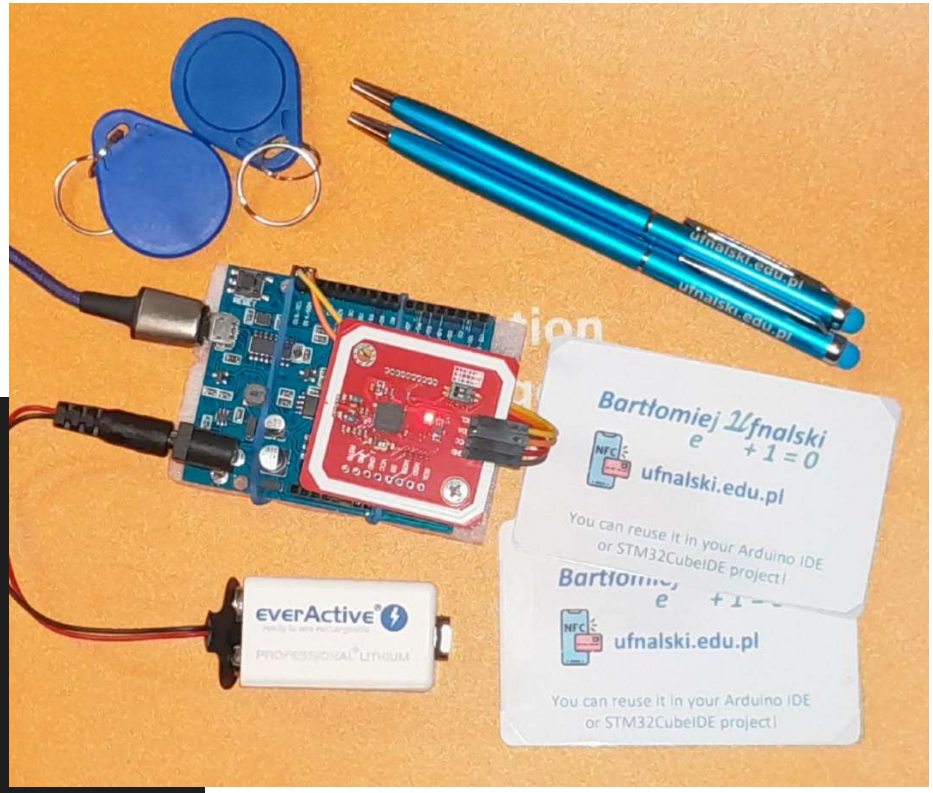
https://github.com/ufnalski/apa102_pov_clock_sync_c562re

Move in any direction you want! [Demo 8/8]



https://github.com/ufnalski/omni_wheel_holonomic_robot_c562re

Let’s do (a) business (card)!




```
Found chip PN532
Firmware ver. 1.6

Scan a NFC tag

NFC Tag - Mifare Classic
UID E8 9E DA 0D

NDEF Message 1 record, 27 bytes
  NDEF Record
    TNF 0x1 Well Known
    Type Length 0x1 1
    Payload Length 0x17 23
    Type 55  U
    Payload 00 68 74 74 70 3A 2F 2F 75 66 6E 61 6C 73 6B 69 2E 65 64 75 2E 70 6C  .http://ufnalski.edu.pl
    Record is 27 bytes

Scan a NFC tag
```

https://play.google.com/store/apps/details?id=com.wakdev.wdnfc
https://www.instructables.com/PCB-Business-Card-With-NFC/

„Your brand is what other people say about you when you’re not in the room” (Jeff Bezos)



Let’s do a business card using NFC Tools



https://play.google.com/store/apps/details?id=com.wakdev.wdnfc
https://qr.io/

Final remarks

- Doing maths helps you grow the mindset of a problem solver. Use math to solve real-life problems. Become an engineer! Look around you and do **the** math, it's engeneers who make the modern world possible :)
- Read books by engineering gurus who resonate with you. I can recommend an entry-level book by Eric Bogatin „Signal and Power Integrity – Simplified".

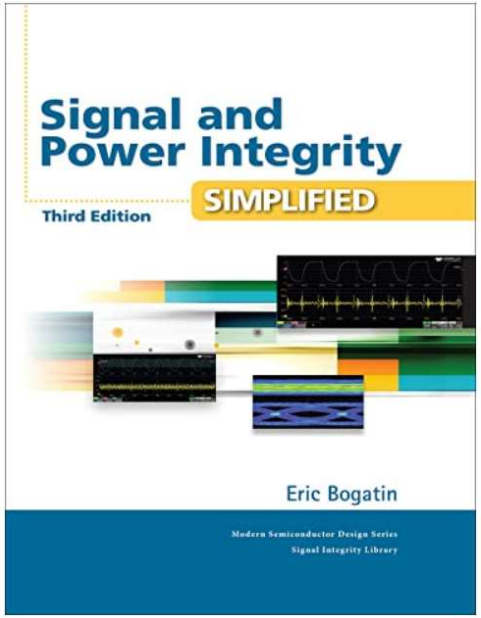
Bogatin's 20 Rules for Engineers

2.The way to separate myth from reality is by "putting in the numbers" with rules of thumb, approximations and numerical simulation tools. (can you tell this process is an incredibly valuable skill?)

9.Never perform a measurement or simulation without first anticipating the results you expect to see. Never believe a measurement or simulation blindly. If it doesn't match what you expect, there is a reason for it. Either there is something wrong in the setup of the tool, or maybe your intuition is off, in which case this is an opportunity to re-calibrate your engineering intuition. Do not proceed with the result unless you can convince yourself it is reasonable. (Rule #9 is so popular, it now appears on hats)

17.An expert is someone who has already made all possible mistakes.

https://engineering.ontariotechu.ca/current-students/current-undergraduate/academic-advising/5600_feas_2023_letterstoayoungeng_book_v4_digital.pdf
https://www.signalintegrityjournal.com/blogs/4-eric-bogatin-signal-integrity-journal-technical-editor/post/1539-bogatins-20-rules-for-engineers



Start experimenting already on your way back home!



https://phyphox.org/



Thank you for your kind attention!



WARNING

Control engineering – do try this at home!